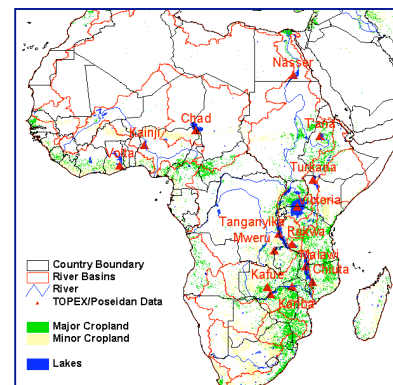
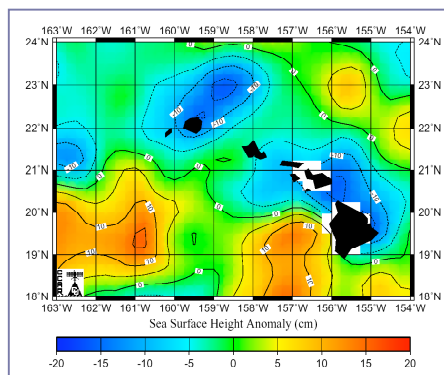
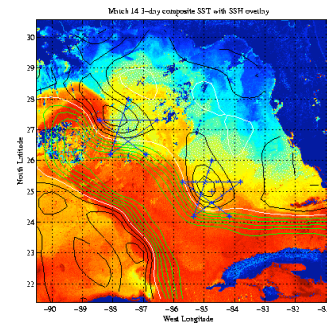
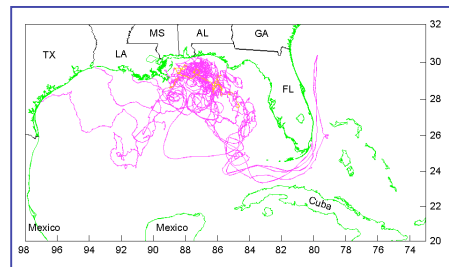
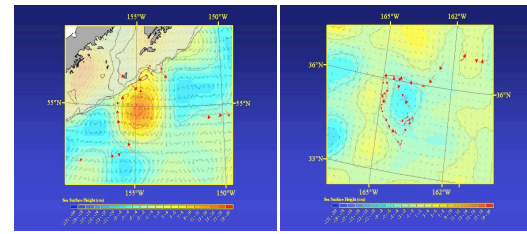
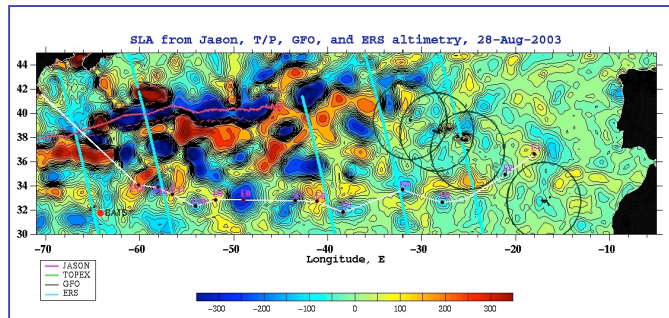




Space

ship-to-Shore: Society Benefits from Ocean Altimetry Data





Some facts...current savings



- Annual economic return to U.S. economy of El Niño forecasting systems: between 13 & 26%.
- Farmers get about \$15 of value out of every dollar spent forecasting the weather.
- Worldwide agricultural benefits of better El Niño forecasts are at least \$450 to \$550 million per year.
- Increase in warning lead-times decreases deaths & injuries, & provides substantial monetary savings as well.
- \$1.1 billion decrease in storm losses in California in the 1997-1998 El Niño as compared to the 1982-1983 El Niño.





Some facts...potential savings



- The annual cost of electricity could decrease by at least \$1 billion if the accuracy of weather forecasts was improved by just one degree F.
- In the U.S., about 1/3 of the GDP is climate/weather sensitive; \$3 trillion is at risk in agriculture, finance, insurance and real estate, retail and wholesale trade, and manufacturing.
- A 1°C SST increase in the equatorial Pacific in August results in a fall in the Indonesian rice harvest of more than 1 million metric tons, and world rice prices rise about 10%.*
- Better ocean observations can reduce the overall cost of oil pollution incidents by improved deployment of oil-spill clean-up equipment.
- With more accurate forecasts, ships at sea can make route corrections to take advantage of favorable weather and currents and avoid hazardous weather sooner, thus saving time and money.
- In pure economic terms, studies show that national institutions providing weather, climate, and water services to their citizens contribute an estimated \$20-\$40 billion dollars each year to their national economies.



Source: EOM magazine, August/September 2003

*W.P. Falcon, Stanford University

CLIMATE

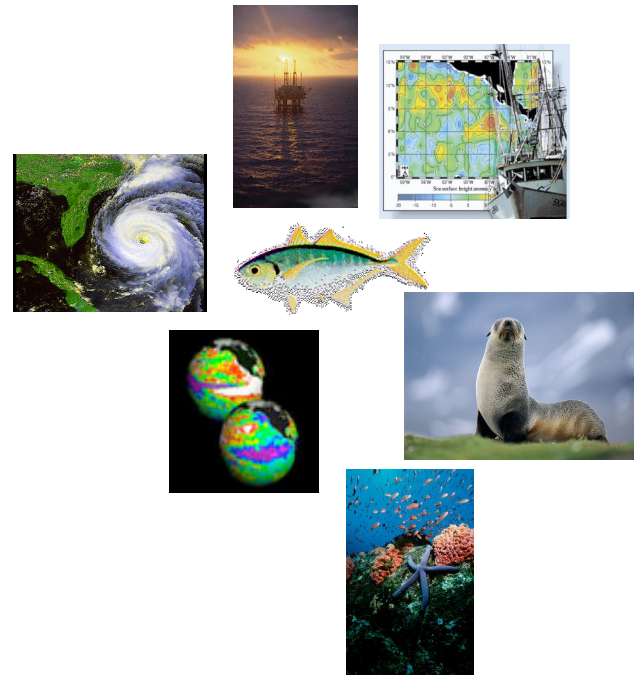
- **Climate Research:** By modeling changes in the distribution of heat in the ocean with TOPEX/POSEIDON & Jason data, scientists can study patterns of evaporation and resultant precipitation in the ocean system.
- **Hurricane Forecasting:** Altimeter data are incorporated into atmospheric models for hurricane season forecasting and individual storm severity.
- **El Niño & La Niña Forecasting:** Understanding the pattern and effects of climate cycles such as the El Niño Southern Oscillation (ENSO) is a primary goal of the TOPEX/POSEIDON and Jason missions.

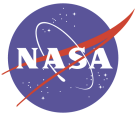
MARINE OPERATIONS

- **Ship Routing:** Maps of currents and eddies from TOPEX/POSEIDON and Jason are used in commercial shipping and recreational yachting to optimize routes.
- **Offshore Industries:** Cable-laying vessels and offshore oil operations require accurate knowledge of ocean circulation patterns to minimize impacts from strong currents.
- **Fisheries Management:** Altimeter data identifies ocean eddies which bring an increase in organisms that comprise the marine food web, attracting fish and fishermen.
- **Ocean Debris Tracking:** Altimeter data can be used to calculate ocean currents to identify likely locations of marine debris which can pose a hazard to coral reefs, marine mammals, and oceangoing vessels.

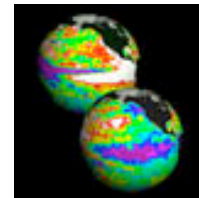
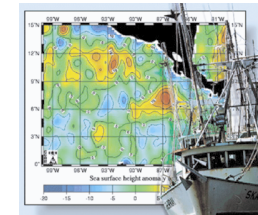
MARINE RESEARCH

- **Marine Mammal Research:** Sperm whales, fur seals, and other marine mammals can be tracked, and therefore studied, around ocean eddies where nutrients and plankton are abundant.
- **Coral Reef Research:** Altimeter data is used to monitor and assess coral reef ecosystems, which are sensitive to changes in ocean temperature due to large-scale climate variability.





Climate

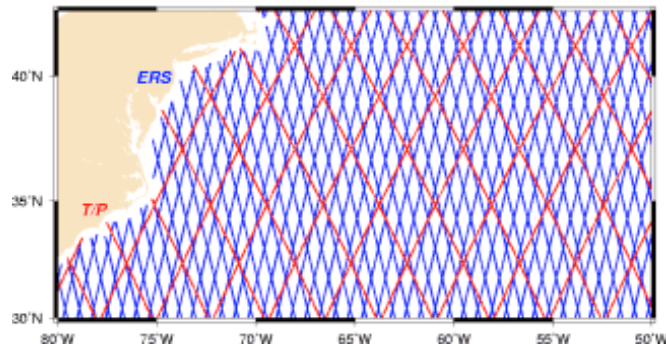




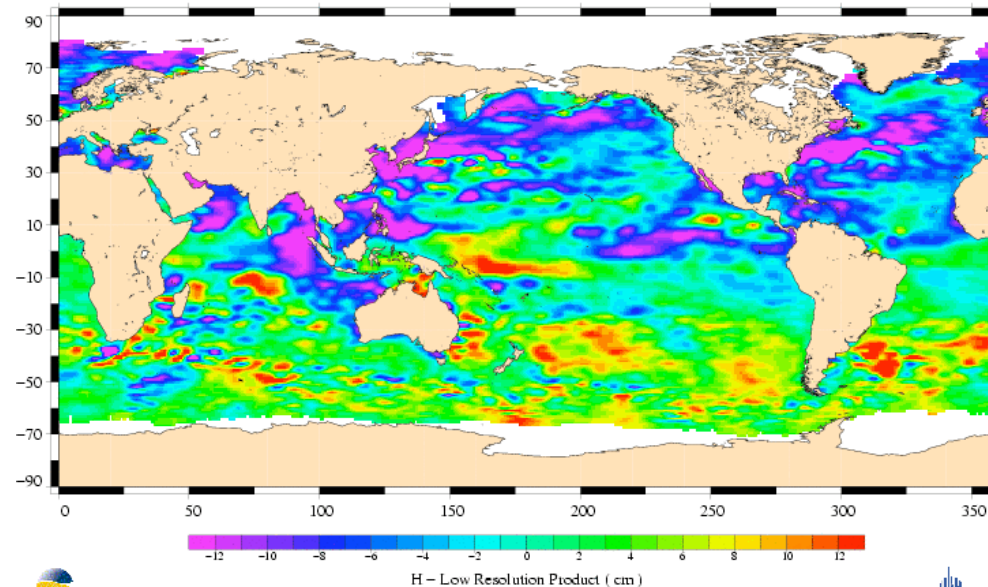
Ssalto/Duacs NRT altimeter products for operational oceanography



SSALTO/DUACS – NRT MSLA – Merged Product
2004/02/28



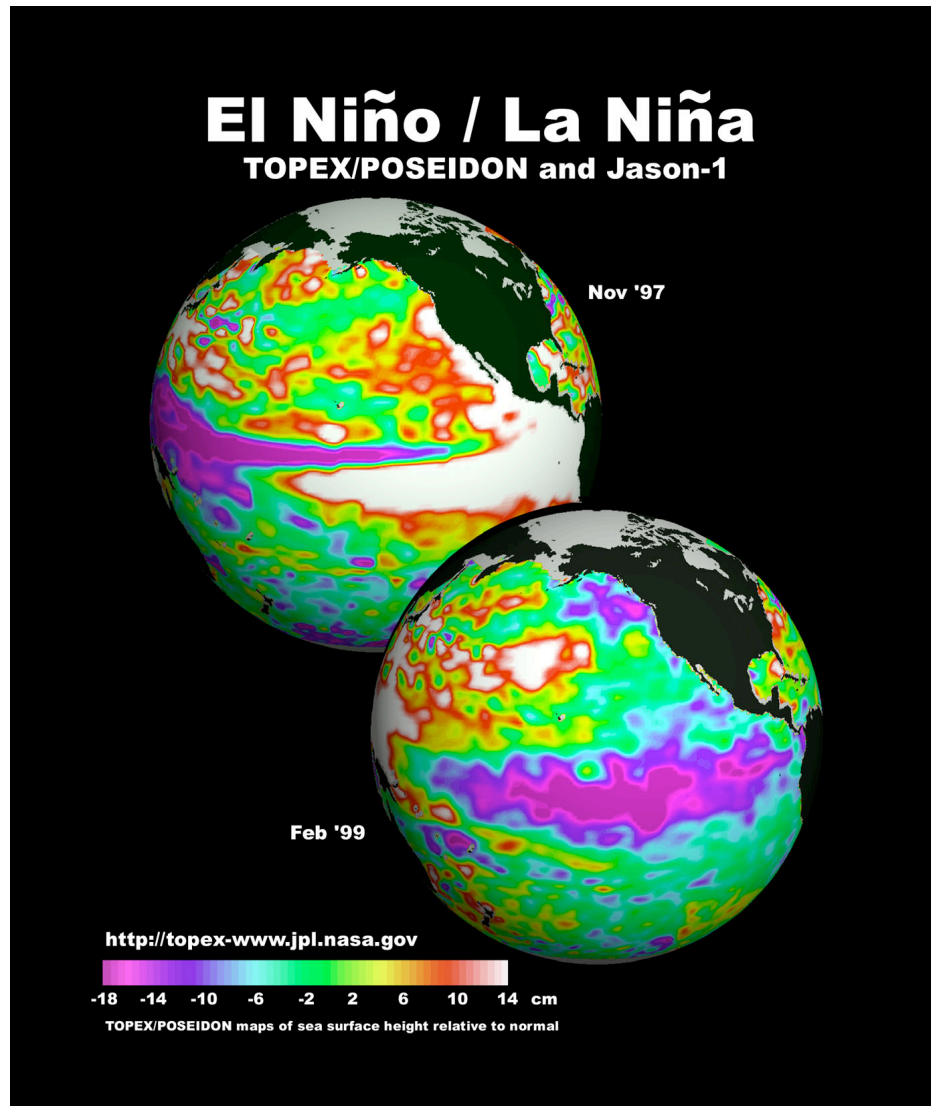
Ground tracks from TP & ERS



The CNES/CLS Ssalto/Duacs (Developing Use of Altimetry for Climate Studies) multi-altimeter processing system provides operational oceanography and climate forecasting centers with high quality near-real time altimeter data. Altimeter data is processed in near real time with sufficient accuracy to improve the skill of climate simulations and, more specifically, seasonal climate forecasts. The NRT and historical products developed and refined with Duacs are widely used in the scientific community. They cover a large spectrum of operational oceanography needs, from mesoscale to climate applications. The data is used in particular for the Mercator project (<http://www.mercator-ocean.fr>), the French contribution to Godae, using IGDR data from all available altimeters. Using data from altimetric satellites with precise orbital determination and combining data from several satellites enables Duacs to produce near-real time homogeneous data with optimal quality.



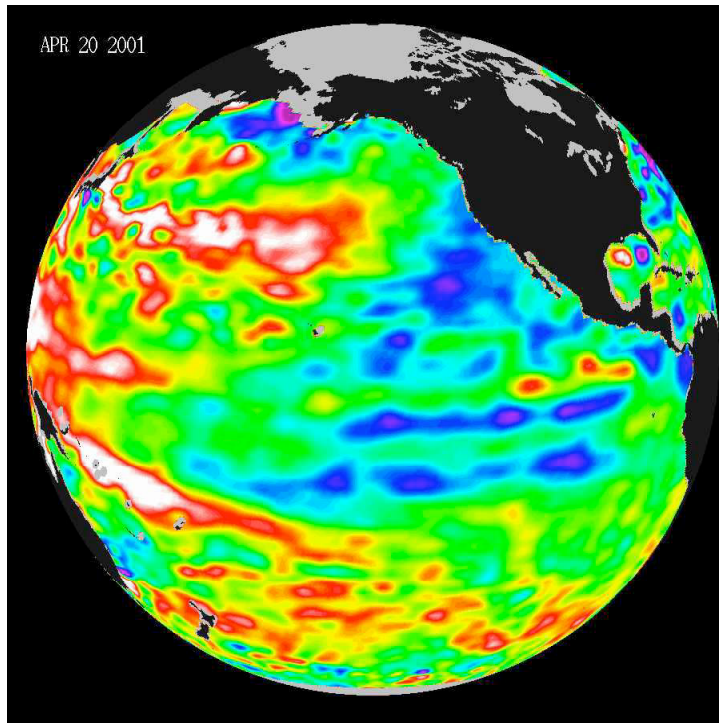
El Niño and La Niña forecasting & monitoring



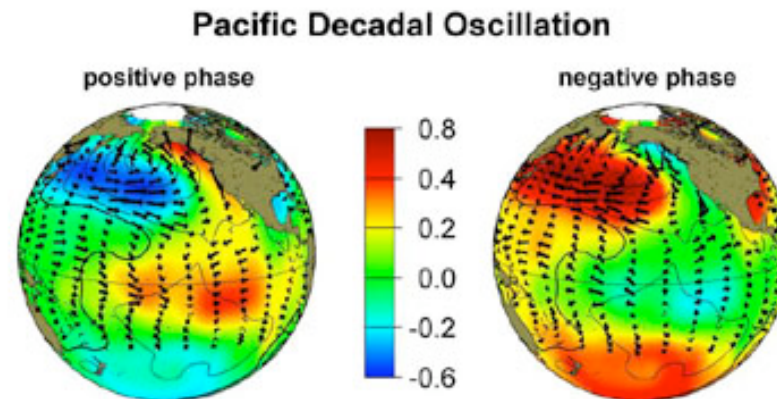
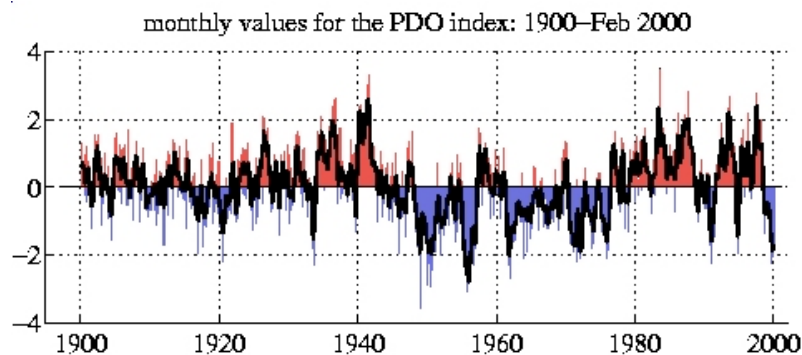
- TOPEX/Poseidon and Jason provide important extended time series monitoring of El Niño and La Niña events
- NOAA's long term climate forecasts, based in part on ocean altimeter data, include flood control, agricultural strategy, water and energy use planning
- Worldwide damage from the 1997-1998 El Niño probably exceeded \$20 billion*. Reliable predictions could help minimize economic impacts.
- Media outlets use the data to explain weather and climate to the public
- TOPEX/Poseidon and Jason data are recognizable to more than a billion people worldwide

Images produced by Dr. Victor Zlotnicki, Dr. Lee -Lueng Fu and Akiko Hayashi, of the Oceans Research Element at NASA's Jet Propulsion Laboratory.

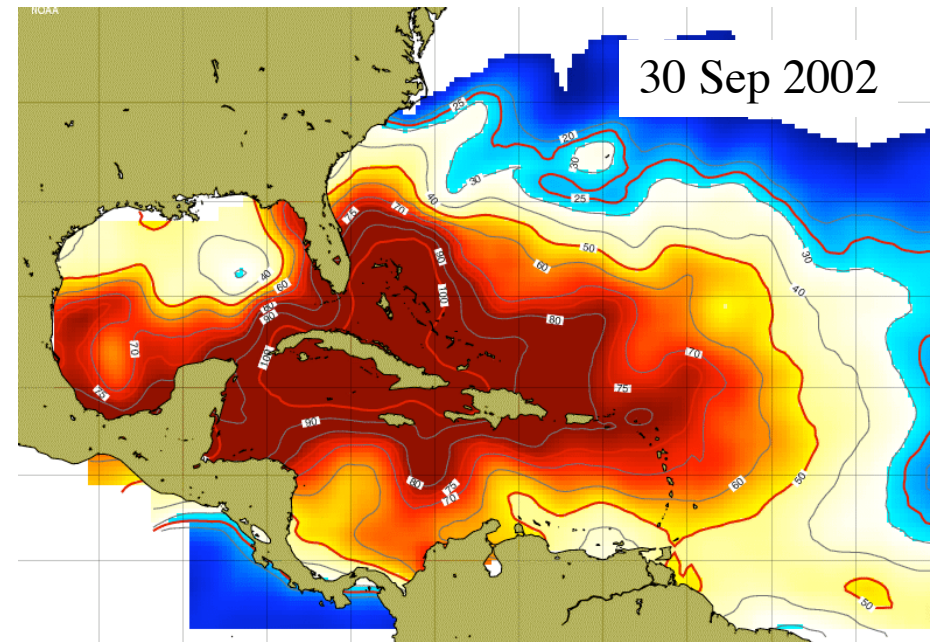
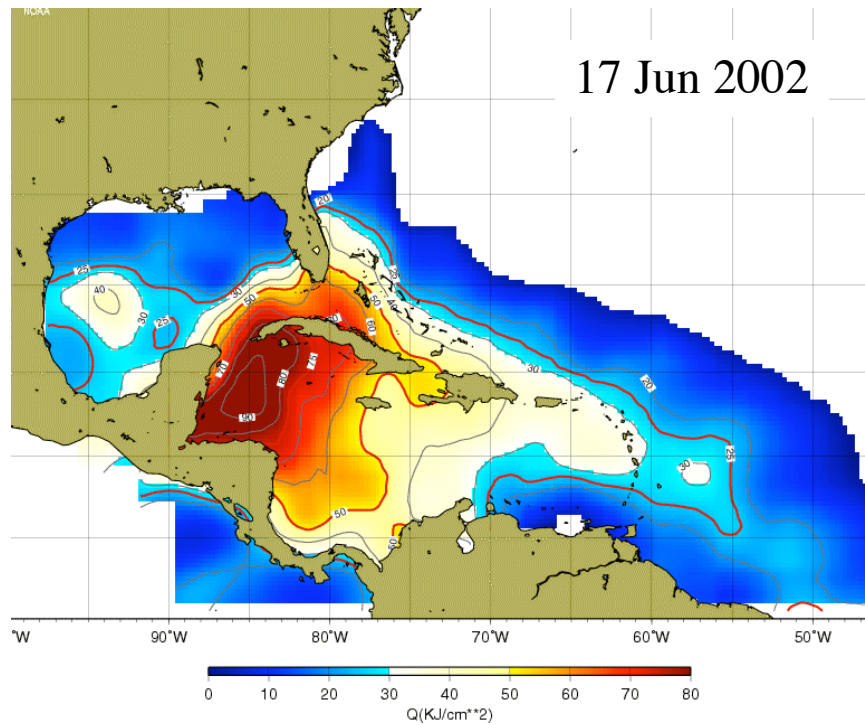
*D. Anderson, European Center for Medium-Range Weather Forecast



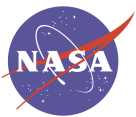
- In this April 2001 image, the Pacific Decadal Oscillation pattern had persisted for three years
- Warm water (high sea levels in red and white)
- Cooler water (lower sea level in blue)



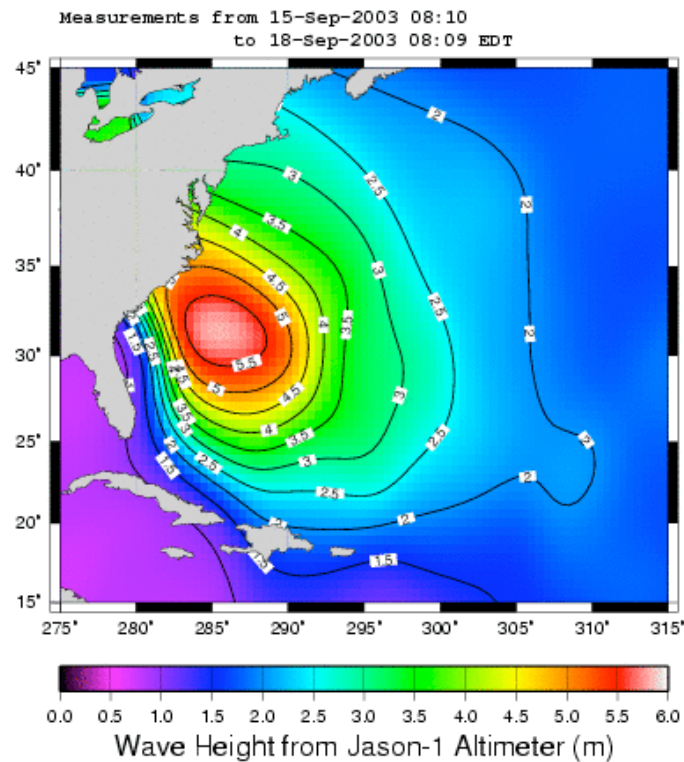
PDO images are courtesy of Nathan Mantua & Steven Hare, University of Washington, Units are degrees Celsius



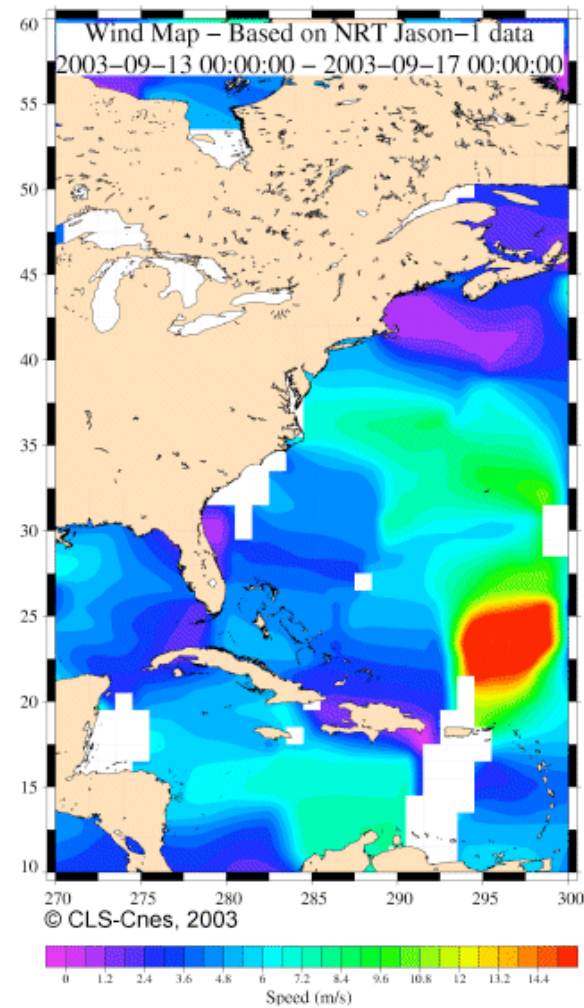
Ocean altimeter data is used for seasonal forecasts of the numbers and strengths of hurricanes expected in a given hurricane season, as well as short term forecasts of the strength of individual hurricanes. These images from the U.S. Naval Research Laboratory illustrate altimetry combined with sea surface temperature data and a two-layer model to show ocean heat potential. Ocean altimetry data is routinely used by the National Hurricane Center for improved hurricane intensity forecasts.



Hurricane watch



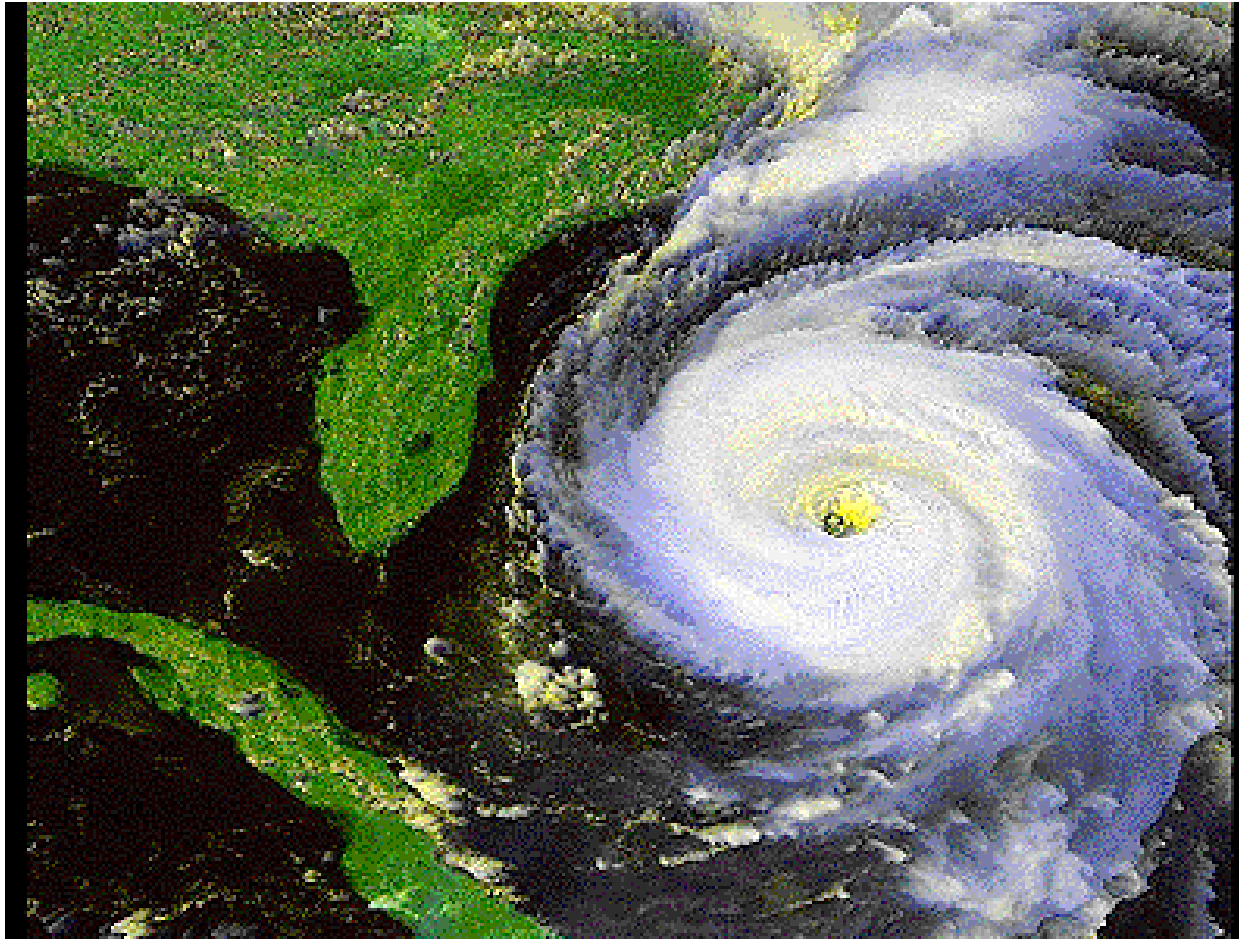
Jason significant wave height data during Hurricane Isabel, September 2003.



Wind data from Jason NRT data during Hurricane Isabel, September 2003.



Hurricane forecasting

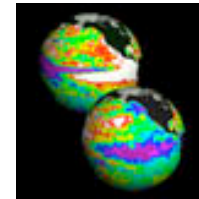
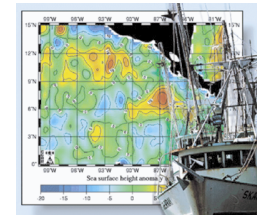
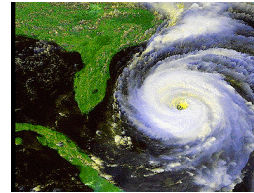


Ocean altimeter data can be used for

- Long-term seasonal forecasts of the numbers and strengths of hurricanes expected in a given hurricane season
- Short term forecasts of the strength of individual hurricanes

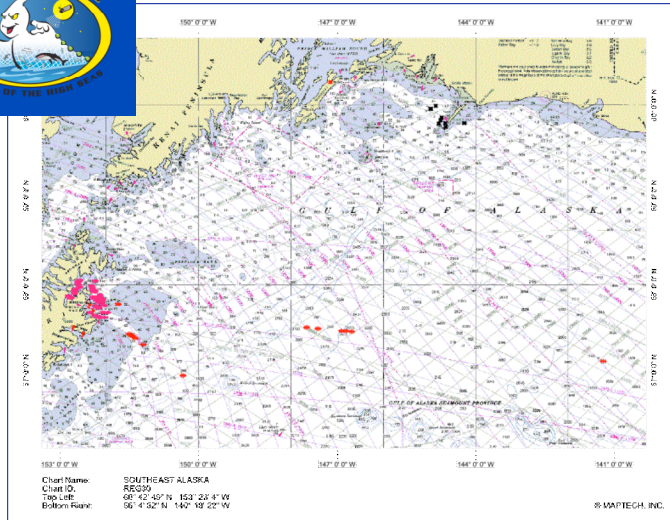


Marine Operations

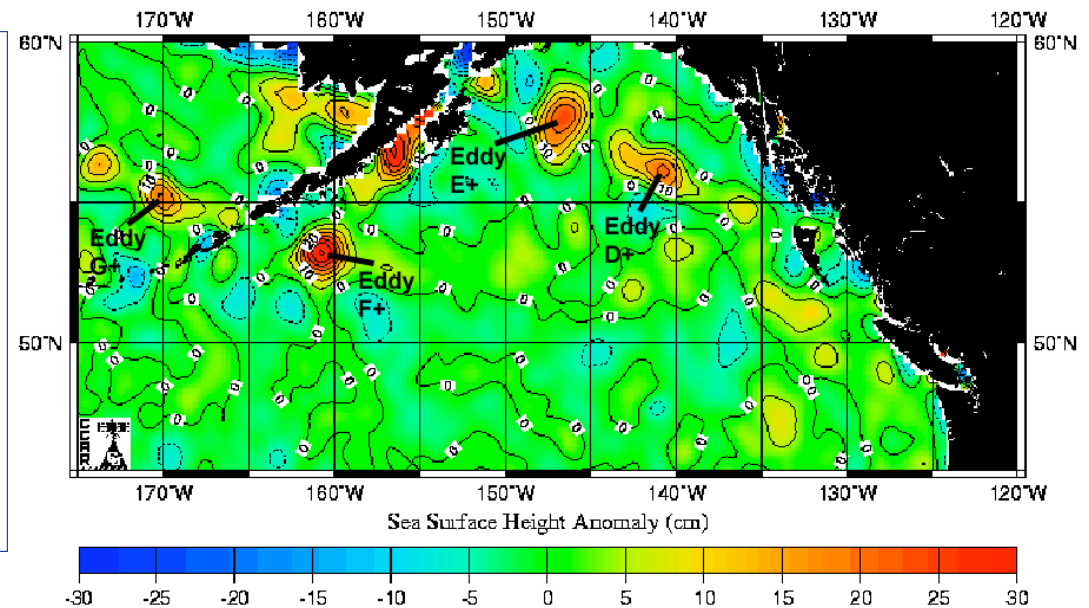




GhostNet Project: Derelict fish net detection



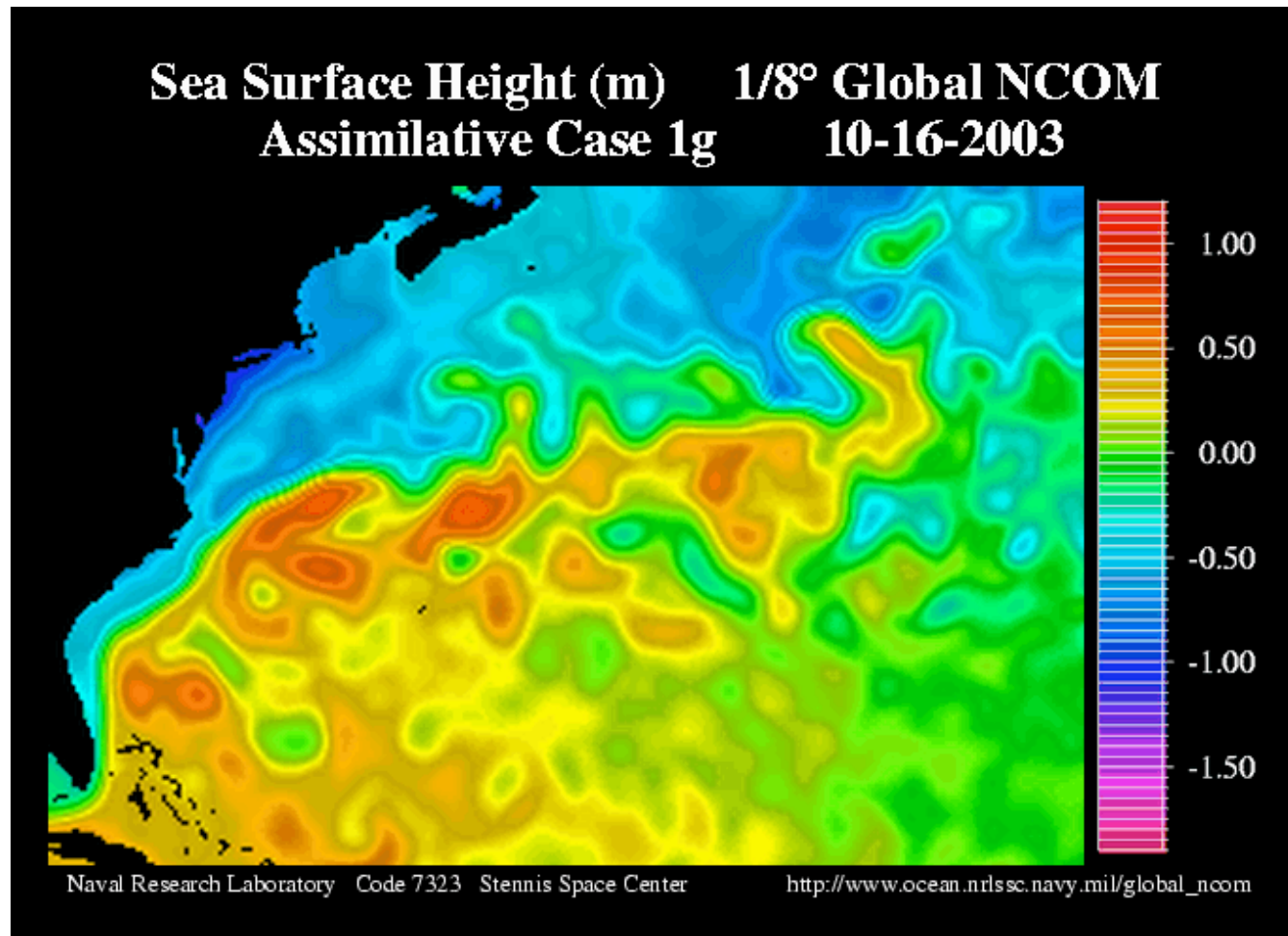
Flight track and debris sightings



Lost or abandoned fishing nets threaten fish, birds, sea turtles, and marine mammals in the open ocean. When entangled in coral reefs, these nets can also damage the reef environment. The GhostNet project (an industry, Government, and academia partnership) utilizes circulation models, drifting buoys, satellite imagery, and airborne surveys with remote sensing instruments in the detection of derelict nets at sea. These components were employed for the detection of marine debris during a 14-day aircraft survey of the Gulf of Alaska. Altimeter data from CCAR at the University of Colorado was among the suite of data used to locate convergent areas where nets were likely to collect. An aircraft survey with visible and IR cameras and a LIDAR instrument located debris in the targeted locations.



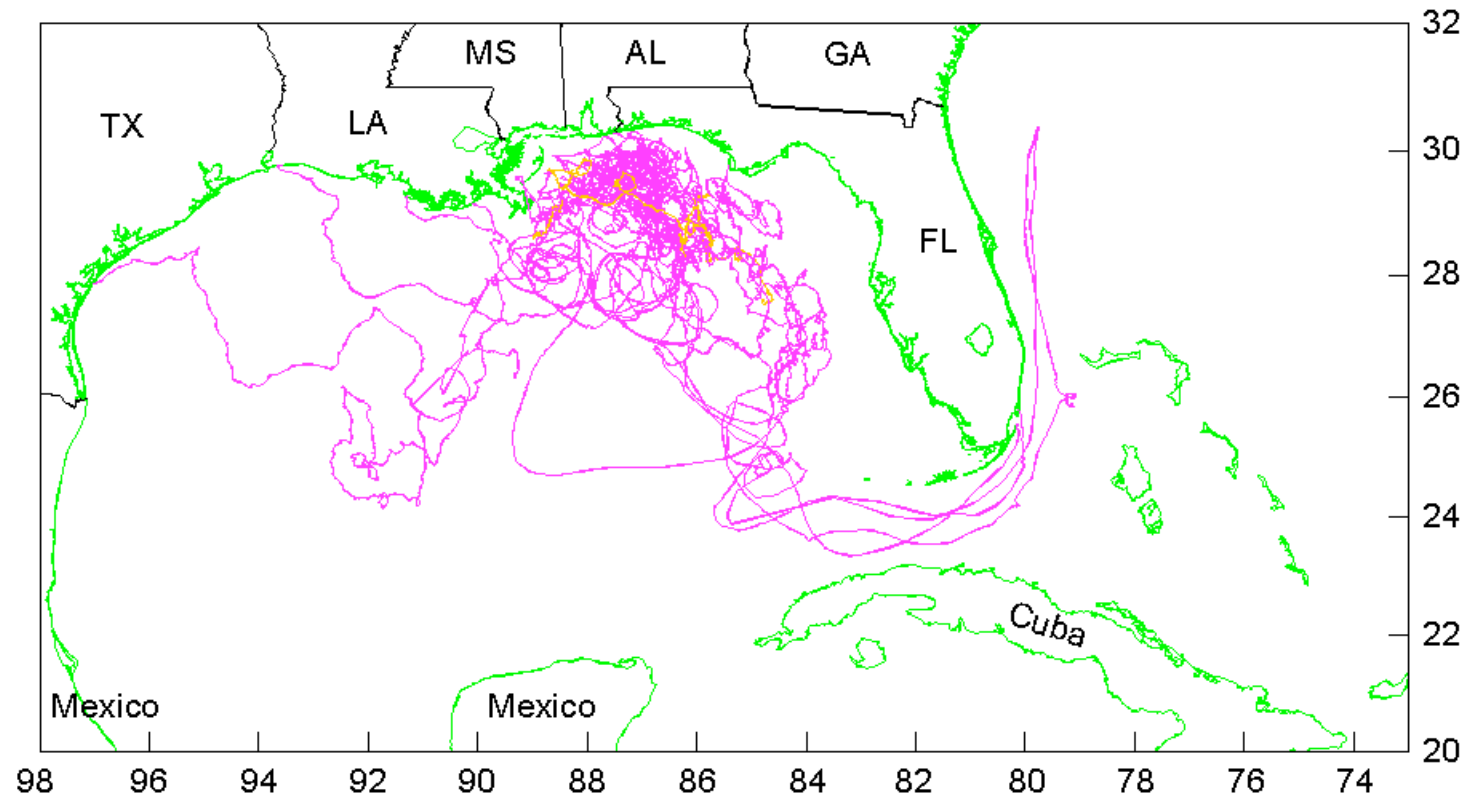
U.S. Navy nowcast system



Global Navy Coastal Ocean Models (NCOM) are updated daily at the Naval Oceanographic Office (NAVOCEANO). This image shows the sea surface height of the Gulf Stream on 16 October 2003.



Simulations of oil-spill trajectories: Gulf of Mexico



Trajectories of oil-spill simulating drifters deployed in the Gulf of Mexico in Nov. 1998 were tracked by the Service ARGOS system for 30 days for the U.S. Minerals Management Service (MMS); some drifters persisted in transmitting longer. Comparisons were then made against computer-model-generated oil-spill simulations using, in part, an ocean current field produced by the Princeton Regional Ocean Forecast System (PROFS) employing data assimilation of CCAR's blended altimeter data products which include TP and Jason data.



Offshore oilfield operational support: Gulf of Mexico



Data User: Capt. Karl Greig, captain of a large anchor handling tug boat owned by Edison Chouest Offshore, a petroleum industry service company, uses NRT Jason data from CCAR to optimize routes while towing semi-submersible drilling rigs used in deepwater oil and gas exploration between lease blocks.

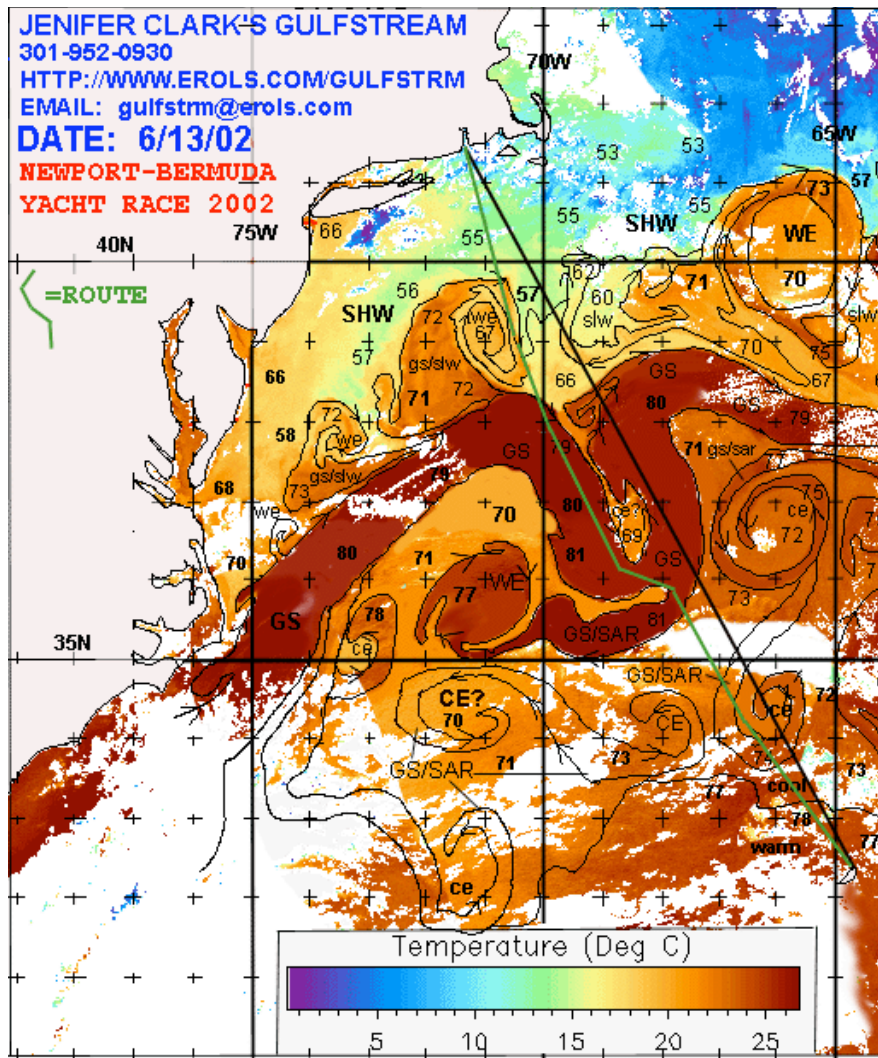
Example Operation: Moving a rig from Mississippi Canyon block 68 to Mustang Island block 68, a total of 425 nautical miles. Typical towing speeds are 3 to 4 knots so avoiding and/or using eddy currents significantly reduces transit times, in this case by over 50 hours.

Altimeter Product Used: Overlays of geostrophic velocity vector on colored magnitudes values accessed on CCAR website by satellite phone.

Estimated Savings: \$650,000 in rig downtime and towing costs for one event.



Jenifer Clark: Gulfstream

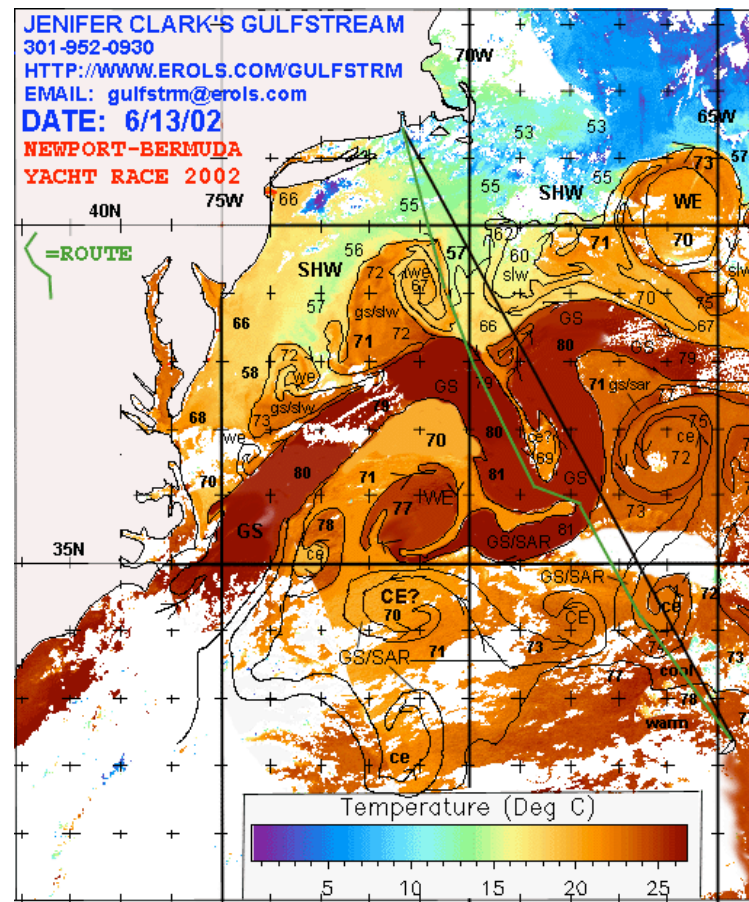
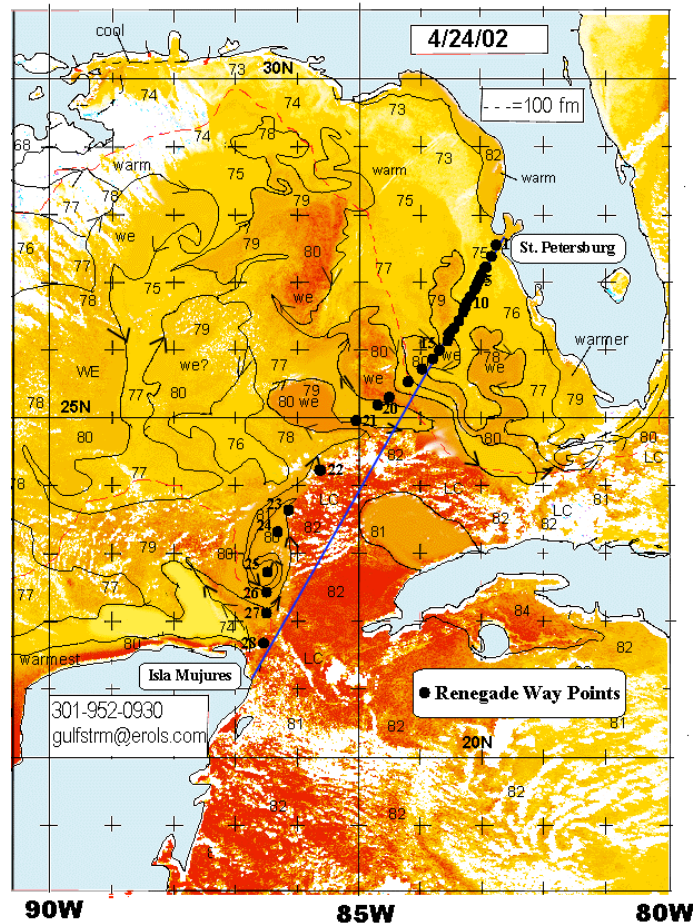


Data User: Jenifer Clark, professional satellite oceanographer.

Application: Provides realtime ocean charts for general marine consulting using infrared, satellite altimetry, and surface isotherm data. Oceanographic analyses are produced and available for the Gulf Stream area and all major global currents.

Operation: Using near real-time altimeter data with sea surface temperature imagery to evaluate currents affecting offshore operations. Waypoints are also provided for taking advantage of favorable currents and for avoiding unfavorable ones.

Altimeter Product Used: Near-real time data SSH and geostrophic velocity data viewers.



Example
optimized routes
for sport sailing

Private companies like Jenifer Clark's Gulfstream make charts of sea surface height. Eddies and swift moving currents are identified and mapped to to increase safety and economic return for recreational boating, transatlantic ship routing, cable laying, and oil exploration



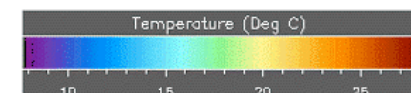
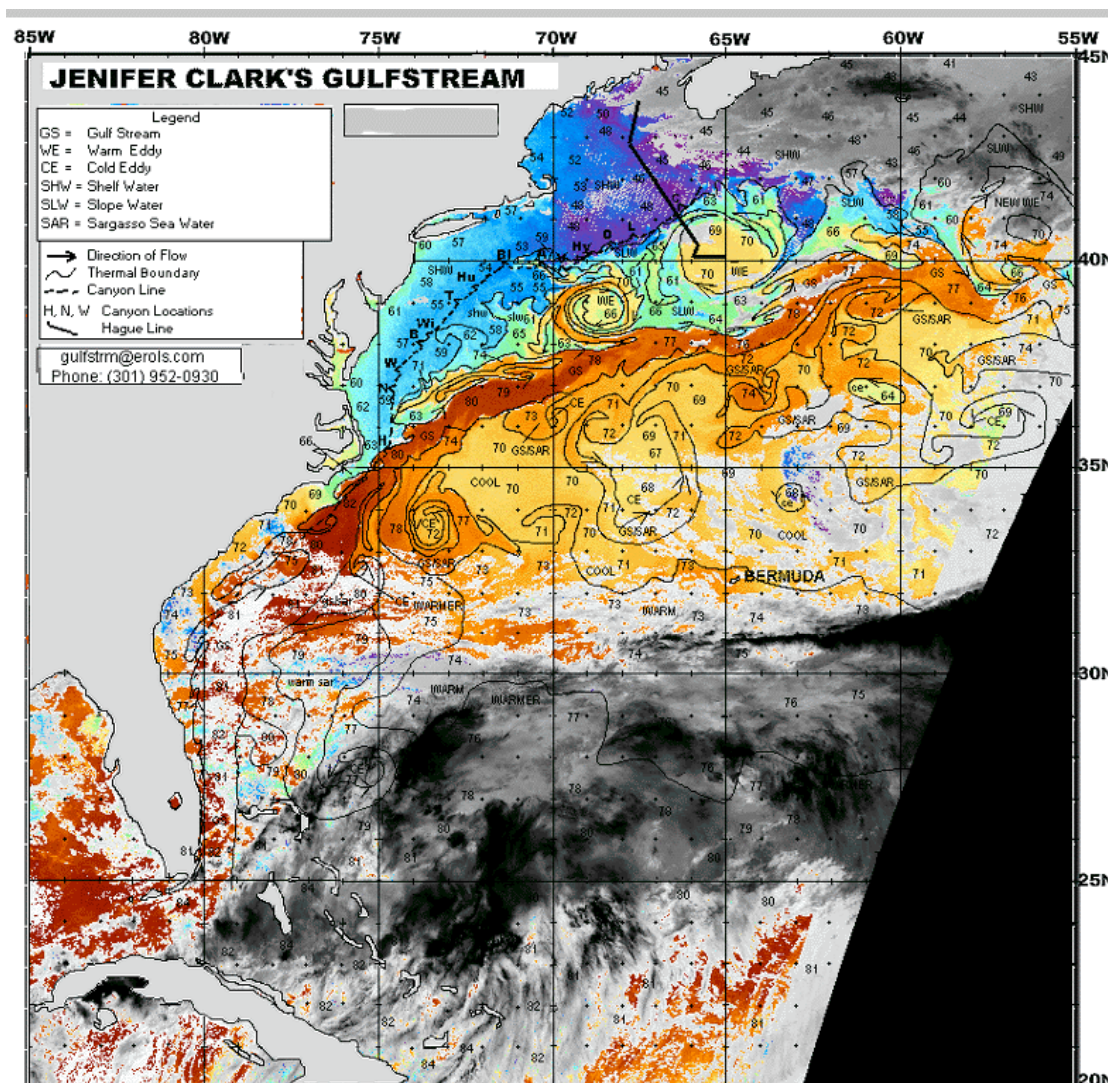
Jenifer Clark: Deep sea recovery



Jenifer Clark assisted Phoenix International Corp. in their recovery of the Navy Helicopter CH-46 near the Gulf Stream in 10,000 ft deep water off of the Virginia coast in June 2002.

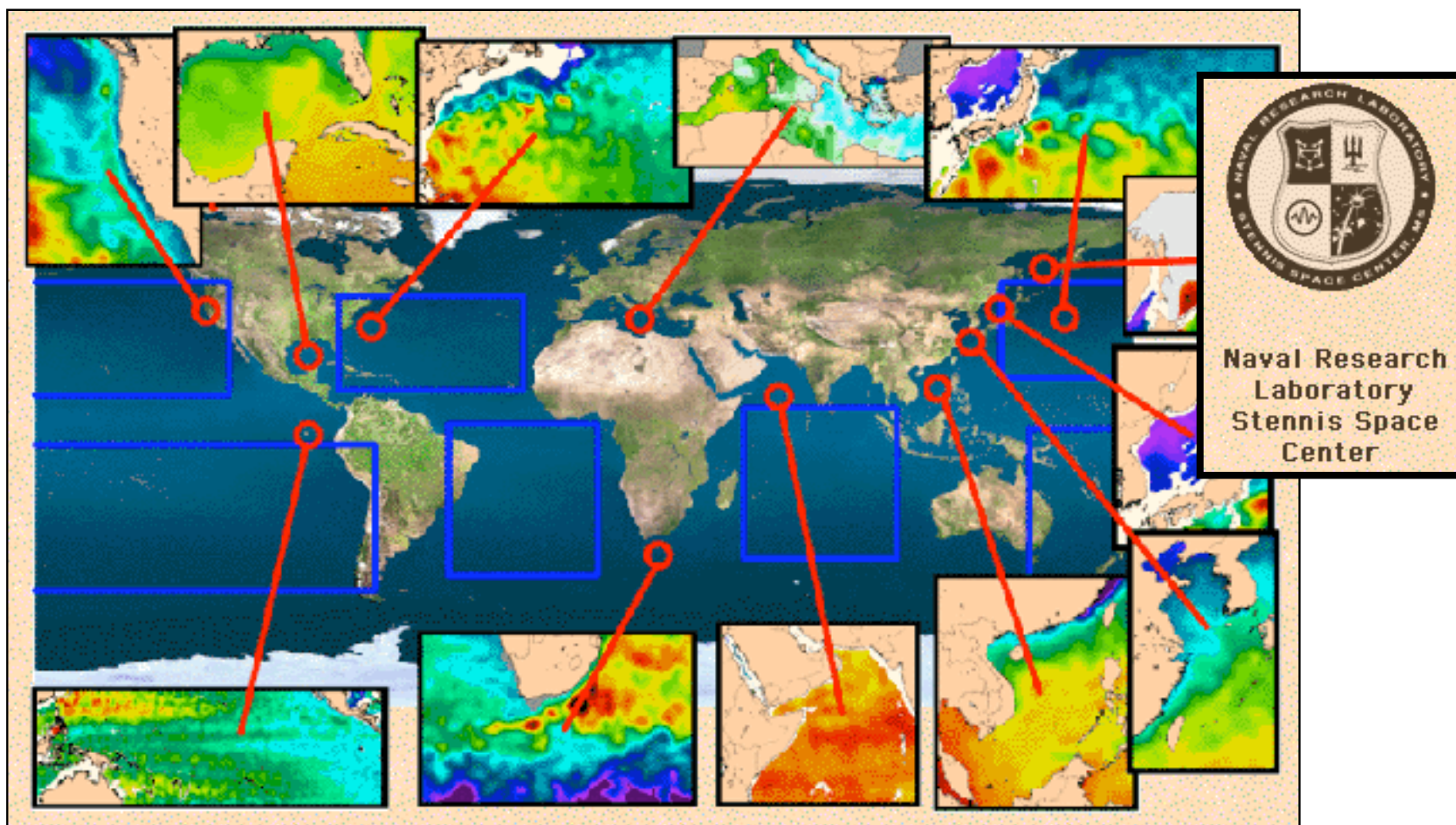
Other activities supported by Jenifer Clark's Gulfstream service

- Sailboat Races
- Ocean Routing
- Sea Surface Temperatures
- Fishing Charts
- Marine Consultation
- Boat Deliveries
- Current Analysis





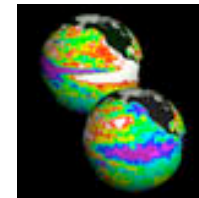
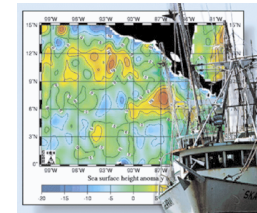
Naval Research Laboratory



The U.S. Navy uses TP, Jason, and GFO to provide global near real-time merged ocean altimetry data for a multitude of applications including tuna tagging, ocean surface roughness studies to aid in tracking oil spills, dynamic climatology studies, and red tide studies in the Gulf of Mexico. (<http://www7300.nrlssc.navy.mil/altimetry/>).

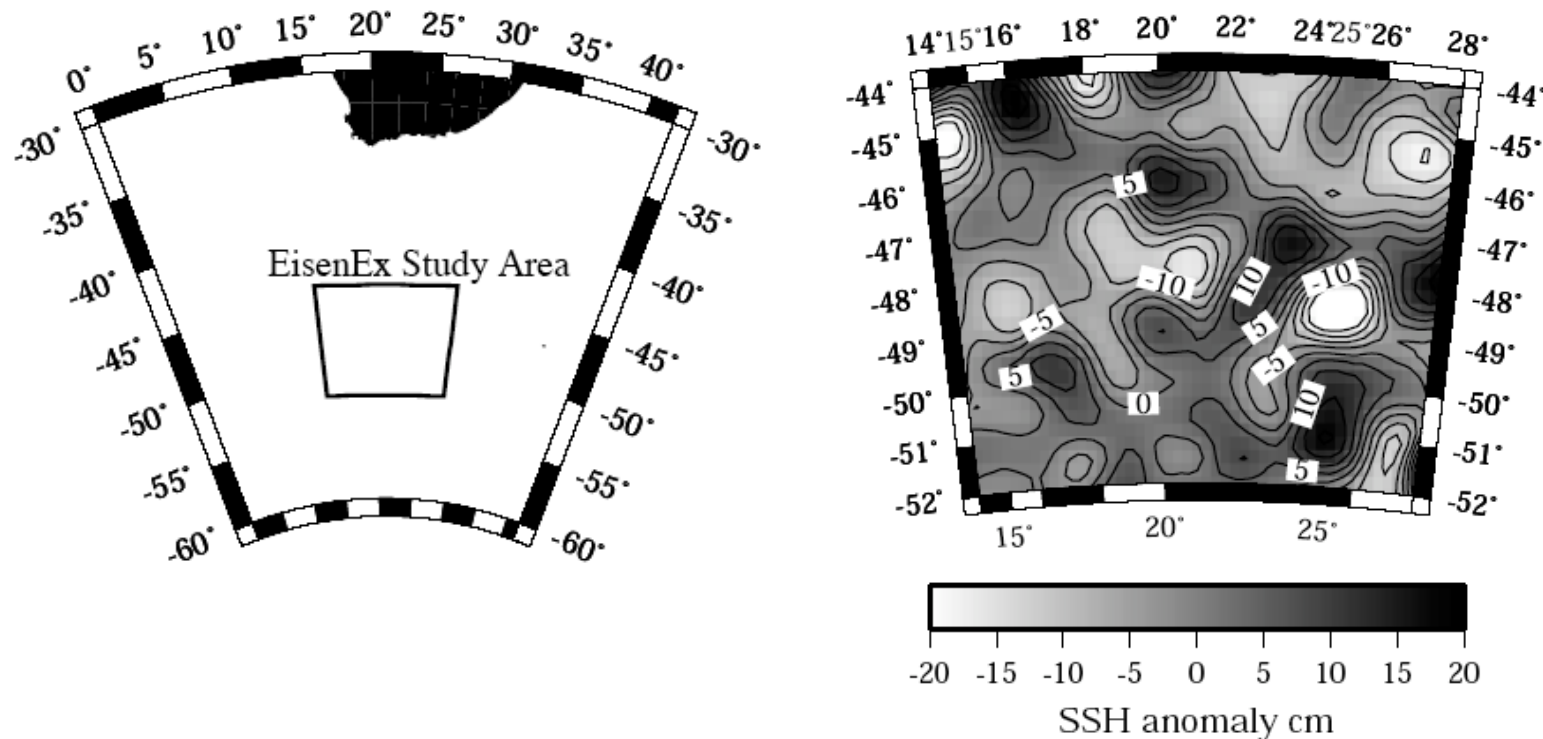


Marine Research





Iron enrichment for biogeochemistry studies

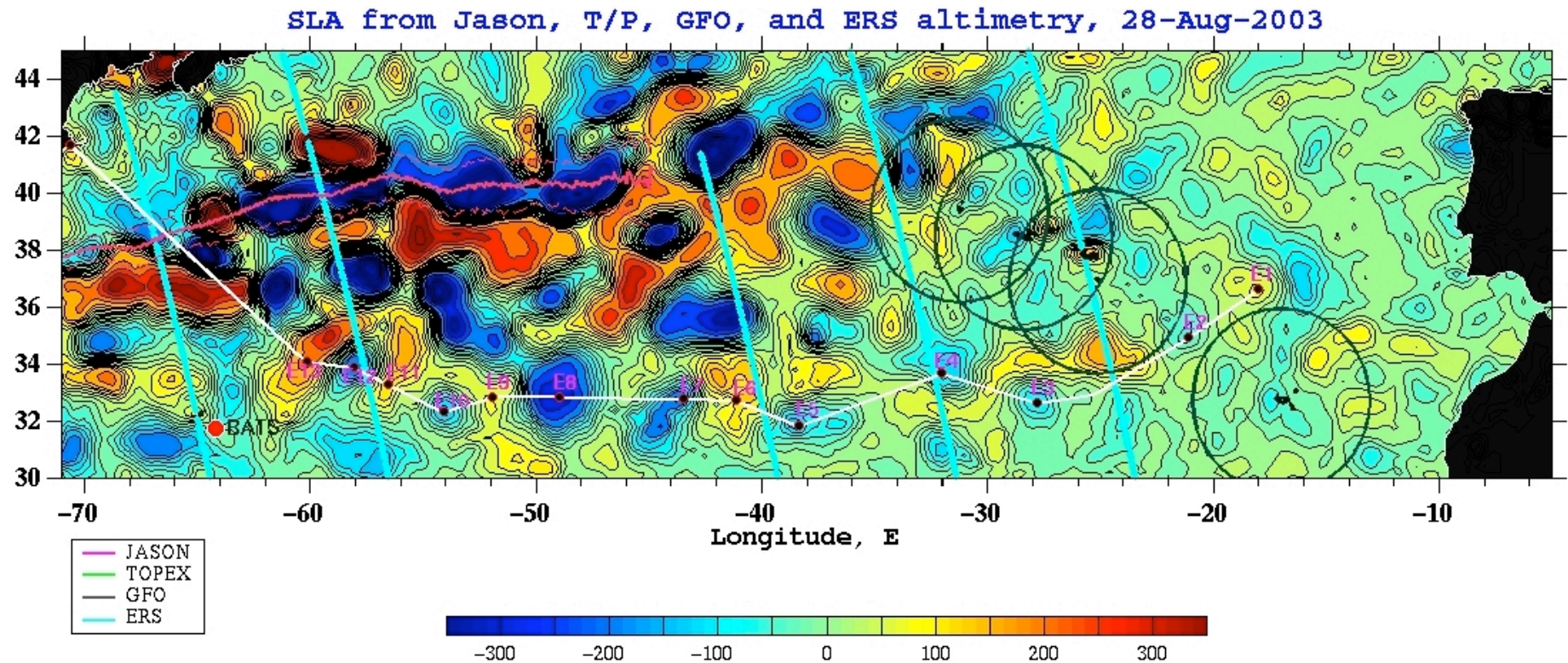


EisenEx is a mesoscale iron enrichment experiment conducted by a German research institute* in a Southern ocean eddy. The eddy, defined with altimeter data, can be seen in the right figure at 21°E 48°S. This and similar experiments are designed to study iron fertilization and its impact on the exchange of carbon between the ocean and air over the Antarctic Circumpolar Current. Over the past decade, scientists have been looking at the ocean iron cycle in more detail to better understand the link between the trace element iron in the ocean and carbon uptake. CCAR mesoscale altimetry has been used in four of nine fertilization experiments to date with near realtime data sent directly to the ship (Polarstern, in this case) during the research cruise. Summaries of these programs can be found at <http://www.bbm.me.uk/FcFert/index.htm>.

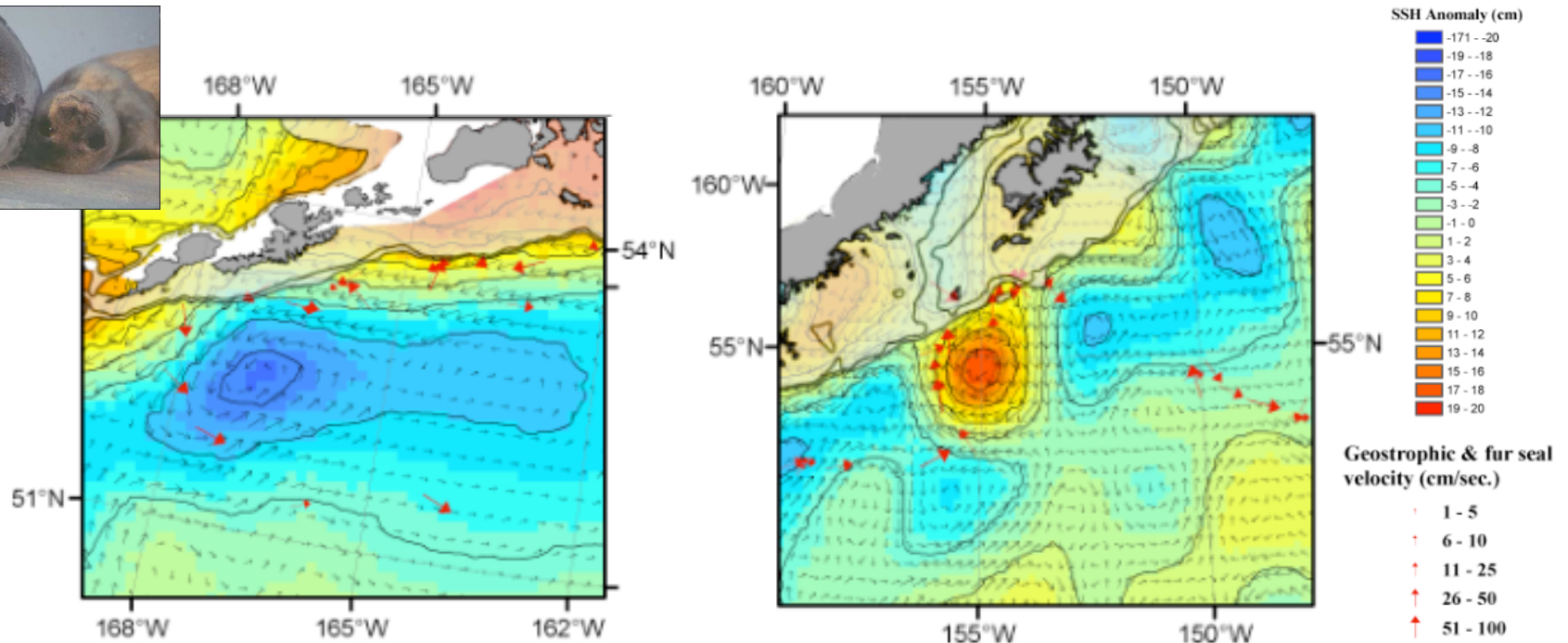
*Forschungsbereich Marine Biogeochemie Chemische Ozeanographie at the Leibniz-Institut für Meereswissenschaften in Kiel



Biologic sampling in eddies



Valery Krosnyrev of Wood's Hole Oceanographic Institution (WHOI) is using along track data from Jason, T/P, GFO and ERS-2 to interpolate mesoscale feature maps that are used to vector R/V Knorr through cyclonic eddies on a transatlantic transect that is in progress. The white line shows the path of the ship. The pink line is the mean Gulf Stream current. The research is biologic in nature.



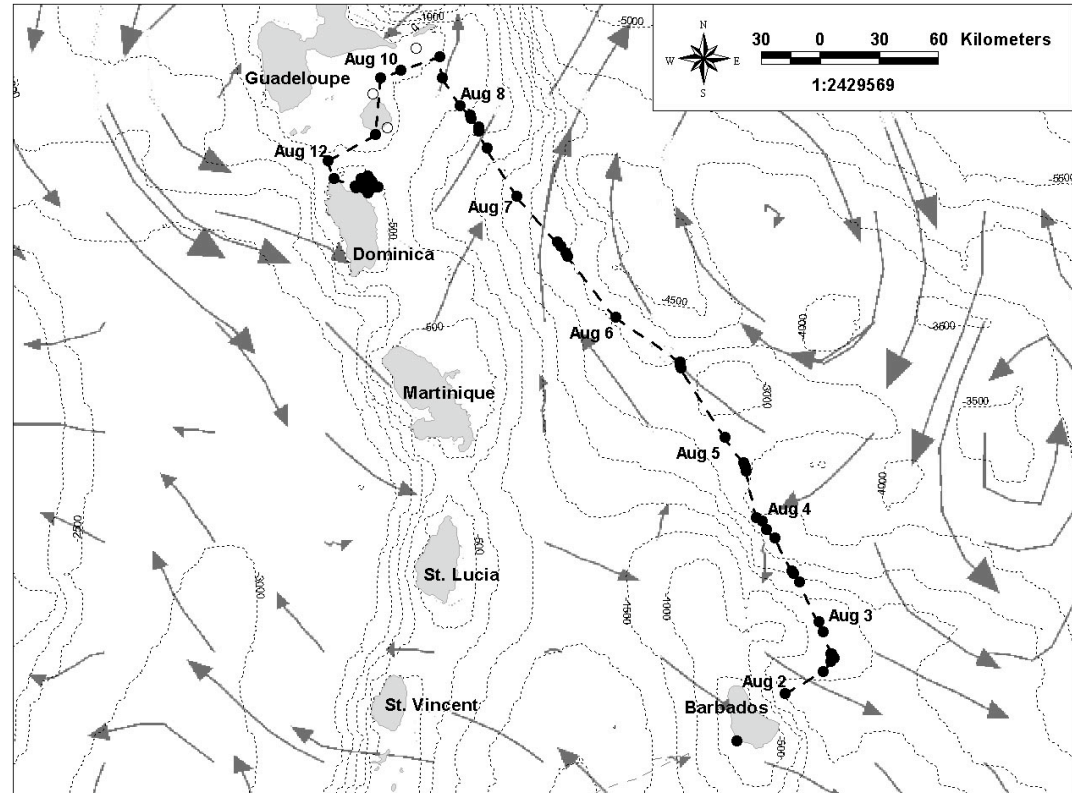
NOAA's National Marine Mammals Laboratory tracks Stellar sea lions in the North Pacific Ocean using blended altimeter data, including TOPEX/Poseidon and Jason OSRs (SSH and current velocity vectors) from the University of Colorado's CCAR group. The data indicates that the sea lions travel 100's of miles across the North Pacific from shore to feed around the edges of ocean eddies. The figure on the left shows a mesoscale cold-core eddy near the Aleutian Islands, and the figure on the right indicates a cold-core eddy spun off the Alaska Stream. Each image is one tagged animal, with red vectors show heading and mean speed on a given day.



Satellite-tracked Sea Turtle migratory patterns



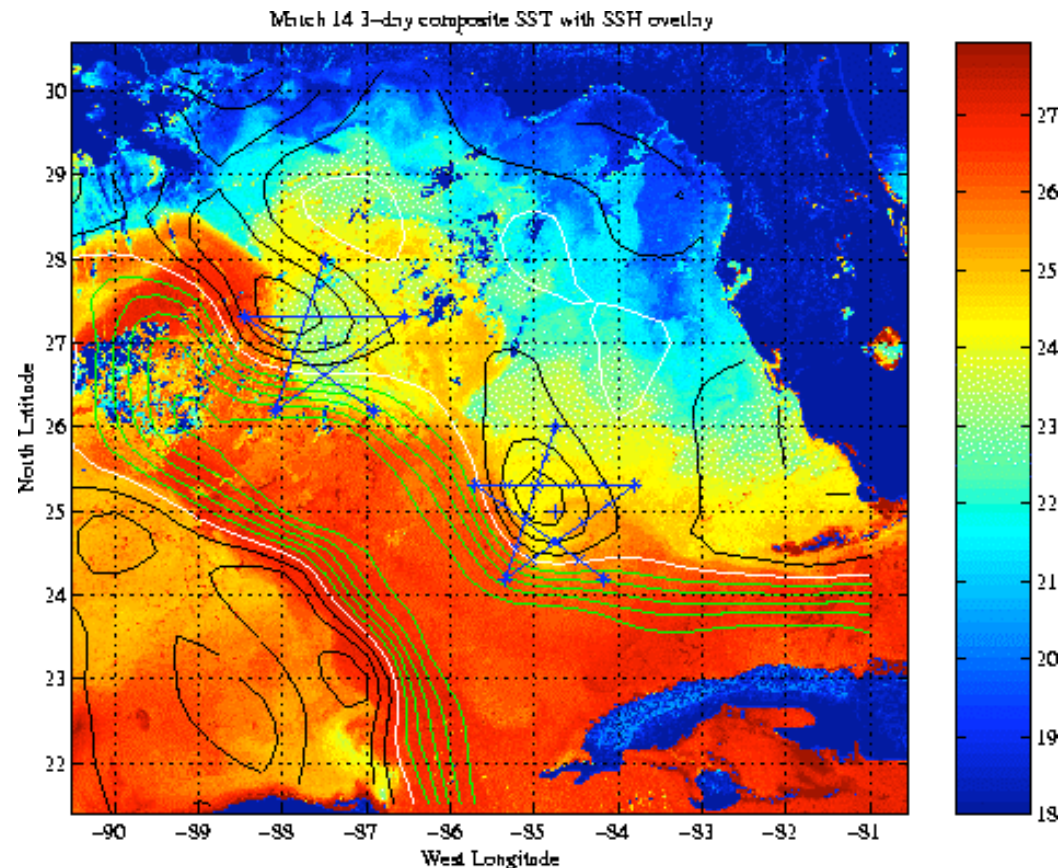
- Seaturtle.org uses CCAR near-real time mesoscale geostrophic velocity anomaly fields
- Study aid on migratory routes of hawksbill turtles in relation to surface eddy fields in near real-time



- Plan is to incorporate the data into graphical interfaces hosted on their web site
- Shown is a migration route from Barbados to Dominica overlaid on coincident geostrophic velocity streamline vectors.



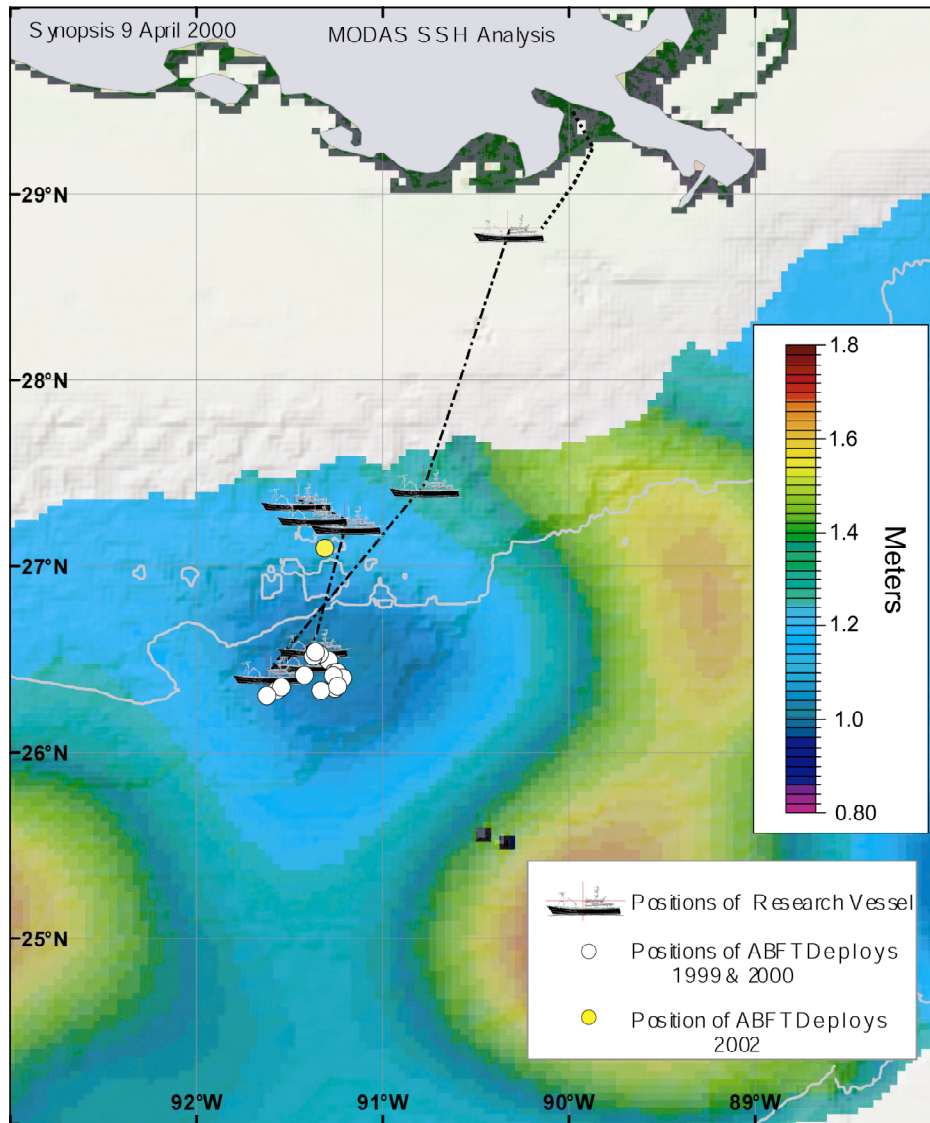
Cetacean surveys in the Gulf of Mexico



The MMS and the NOAA National Marine Fisheries Service (NMFS) conducted studies on sperm whales and deepwater acoustics in the Gulf of Mexico. The CCAR/TAMU cooperation provided NRT analyses of SST overlaid with SSH provided by CCAR using data from TP and ERS-2 altimeters. The example shown above gives suggested locations for XBT surveys of two cyclonic features in which a NOAA Ship searched for sperm whales, between March and April 2001. This application of remote sensing provided a "route map" for marine mammal biologists working aboard the vessel to locate cyclones (biological "oases") and anticyclones (biological "deserts").



Tuna tagging

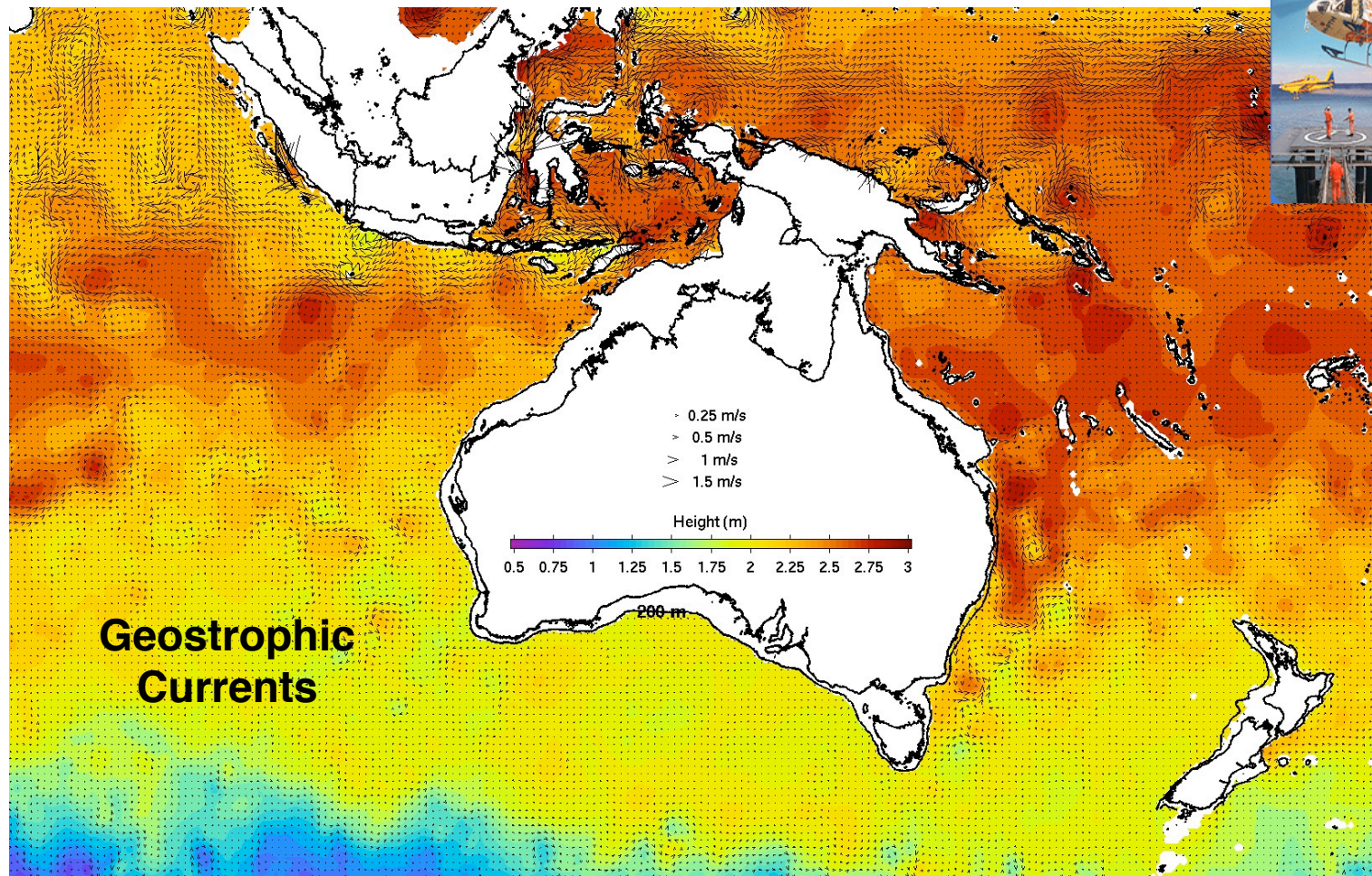


Researchers from the Monterey Bay Aquarium tag tuna using Navy MODAS data assimilation and TP sea surface height analyses

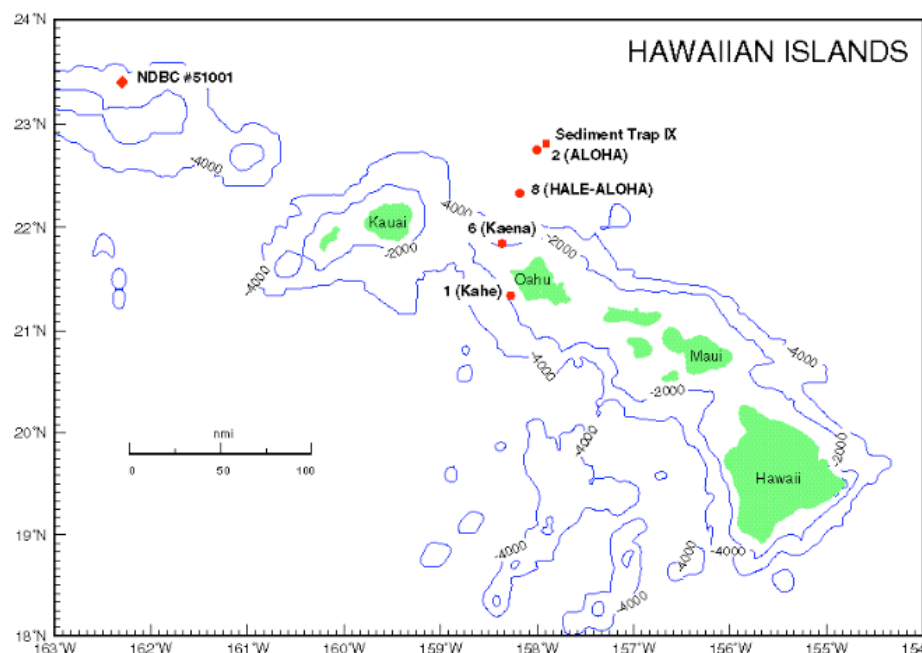




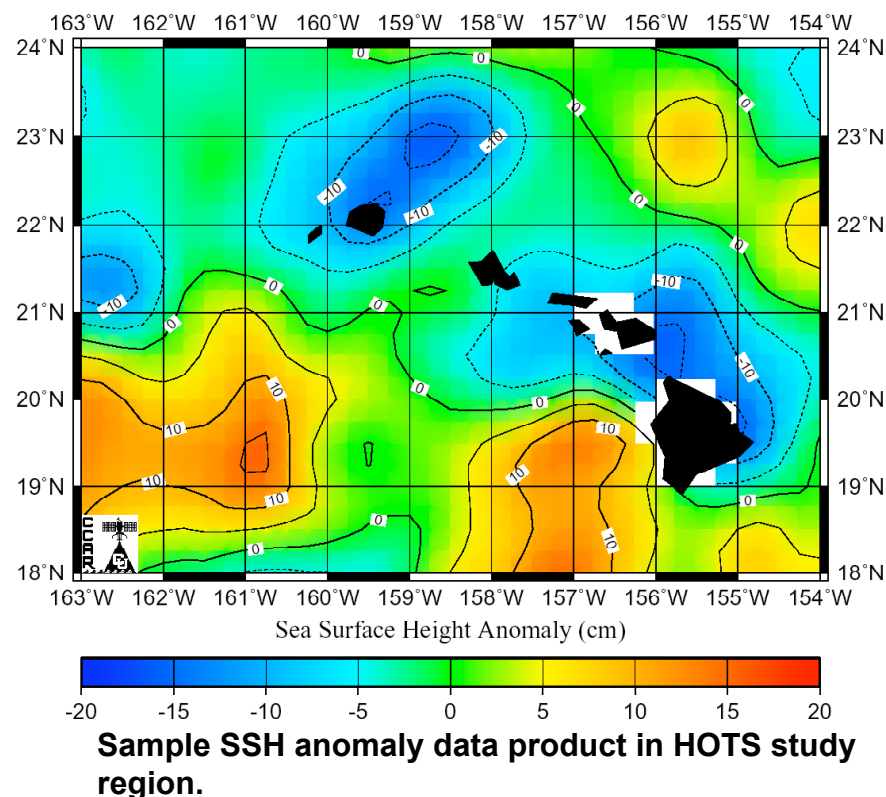
Altimetry for search and rescue: Oil spill tracking in Australia



The Australian Maritime Safety Authority uses geostrophic current data derived from TOPEX/Poseidon and Jason at CSIRO Marine Research for search and rescue operations and oil spill tracking.



The study region is centered on station 2 (Aloha).



Erik Fields, a computing and network technologist working for Professor David Siegel at the University of California Santa Barbara, is using along track Jason data from the CCAR Along-track Data Host (http://www-ccar.colorado.edu/~realtime/global_realtime/alongtrack.html) to make Objective Analysis (OA) maps of sea surface height anomaly at sea. The OA maps will be used with hydrographic surveys and acoustic Doppler current profilers to predict the path of neutrally buoyant sediment traps deployed as part of the VERTIGO sediment transport experiment. This experiment is described at the web page: <http://www.whoi.edu/science/MCG/vertigo>. The cruise worked in the vicinity of the Hawaii Ocean Time-Series (HOTS) Aloha station for several weeks for this study.



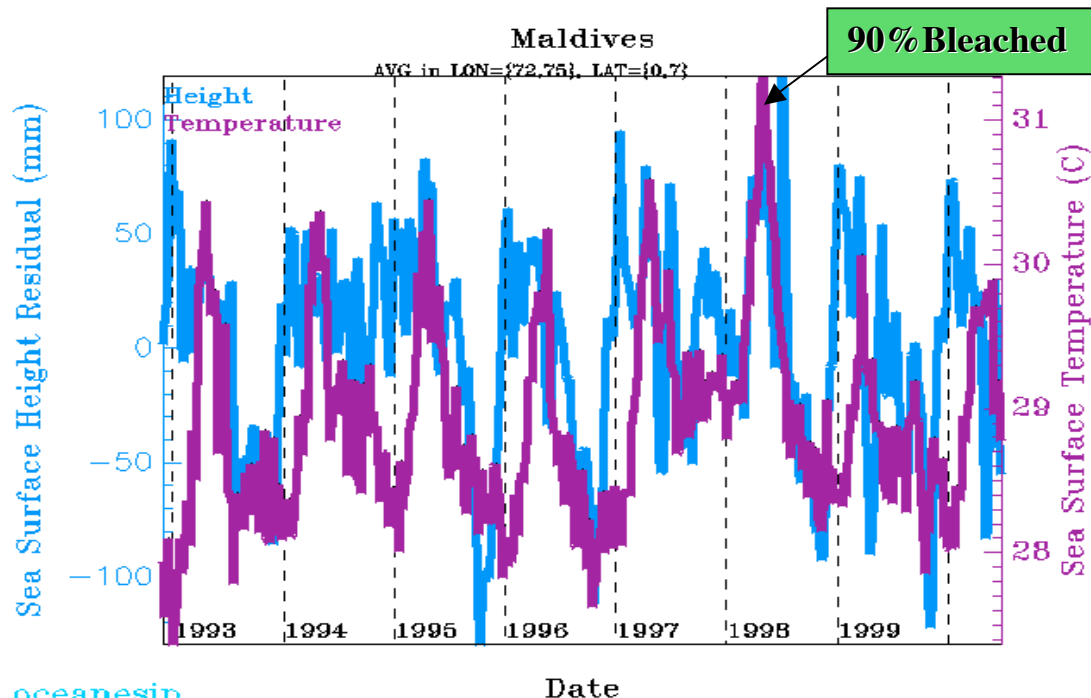
Coral bleaching and climate change



- TOPEX/Poseidon and Jason altimeter sea level and NOAA AVHRR sea surface temperature data monitor and assess global coral reef environments.
- High and low tropical sea levels and ocean temperatures caused by the '97 to '98 El Niño/ La Niña “bleached” 25% of all coral reefs.

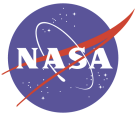


Biodiversity - Coral ecosystems are our oceans “rainforests”

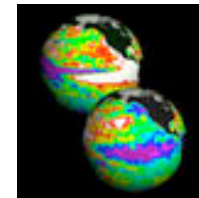
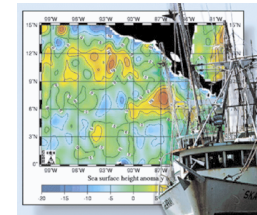
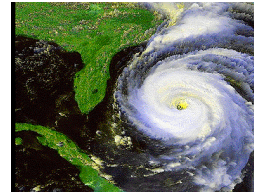


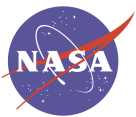
Maldivian Islands, Central Indian Ocean, NASA Landsat 7 image

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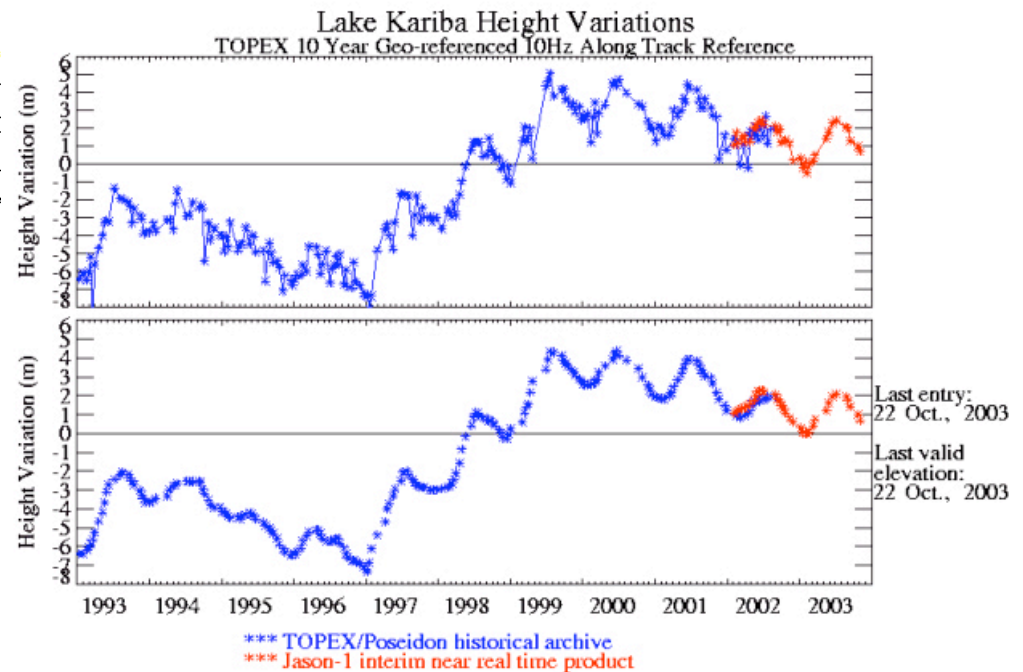
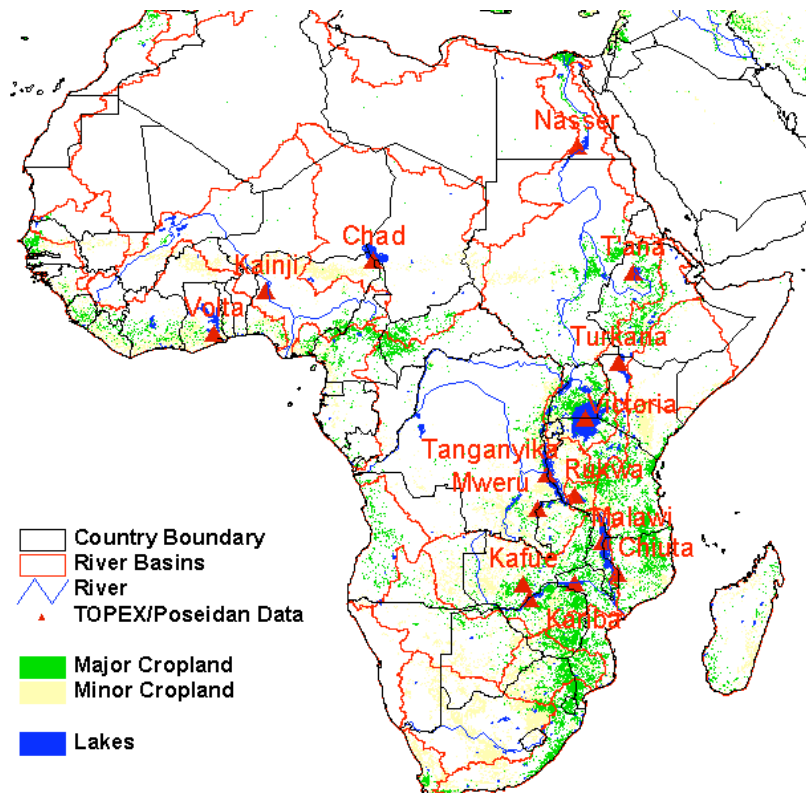


Land Operations





Near real-time measurement of inland waters



Satellite radar altimeters are used to monitor the variation of surface water height of large inland water bodies. Using near-real time Jason data, a time series of surface water height variations is constructed. A data system delivers time series products to a website for public access and to serve the USDA/FAS for its flood/drought investigations. This project is the first of its kind to utilize near-real time altimeter data over inland water in such an operational manner.

Users: Primarily the US Dept. of Agriculture, Foreign Agriculture Service, PECAD division (Production Estimation and Crop Assessment Division), <http://www.fas.usda.gov/pecad>.



Greenland and Simpson Desert

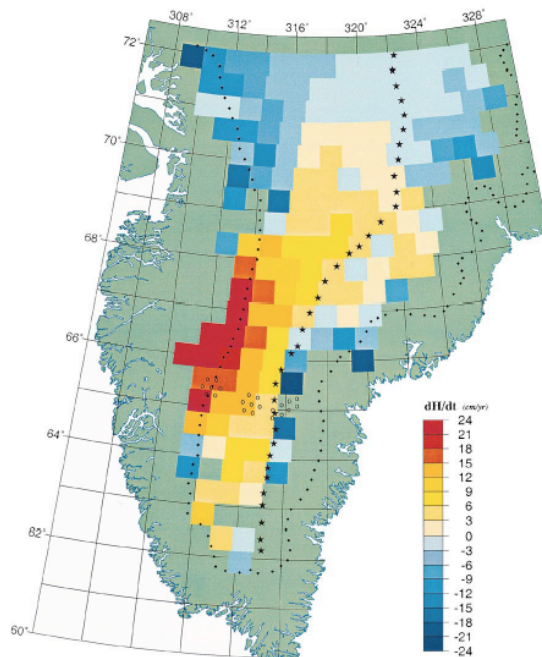


Fig. 5. Spatial distribution of elevation change from 1978 to 1988 from an analysis of Seasat and Geosat altimeter data. The approximate location of the ice divide (star), 2000 m surface elevation contour (dotted), and geocenter scale locations (circles) are also shown. A spatial average of the data yields a growth rate of 1.3 ± 0.6 cm/yr.

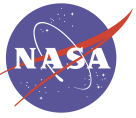


Greenland

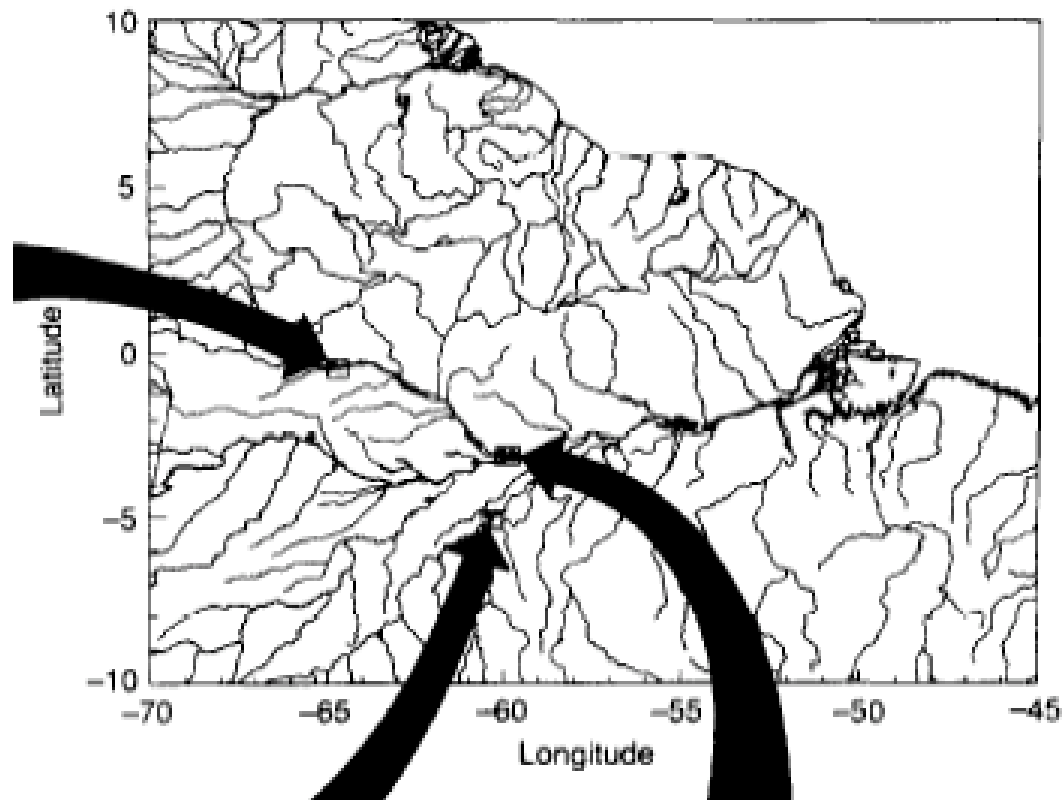
Altimeter data has been used to measure surface elevation change on the southern Greenland ice sheet. Average elevation change from 1978 to 1988 is not significant, contrary to reports that positive ice sheet growth rates suggest increased precipitation due to warmer polar climate.

Simpson Desert, Australia

Radar surface backscattering coefficient, Sigma-naught, is a measure of surface reflectivity. Cycle-to-cycle stability of the computed factor is assessed to discern any temporal changes in the signal.



Amazon River Basin

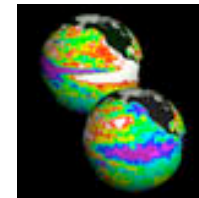
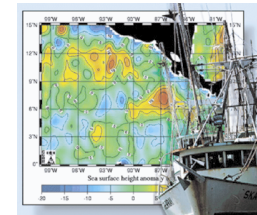


Amazon basin river

Satellite altimetry is used to measure river level variations in areas historically difficult to reach due to large distances, limited access, and low population density (and therefore limited infrastructure) as the Amazon river basin in Brazil.



Other Applications





Other users/applications



- Insurance Claims Adjustors
- Marine Architects
- Fisheries Managers
- Commercial Fishermen
- Search and Rescue
- Ocean Circulation Nowcasts/Forecasts/Hindcasts
- Forensic Oceanographers